Effectiveness of odour repellents for protecting ornamental shrubs from browsing by white-tailed deer

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Big Game Repellent (BGR), SeaCure (a sulfur-containing topical fertilizer), or 3-methyl-2-hexanoic acid (the principal odour in human sweat) were applied to yews (*Taxus* spp.), rhododendrons (*Rhododendron* spp.), or arborvitae (*Thuja* spp.), and the effectiveness of these treatments as white-tailed deer (*Odocoileus virginianus*) odour repellents was evaluated. In experiment 1, 16 residential sites were identified, and three plants at each site were selected for treatment. One plant at each site was covered with Deer-X netting, and another was sprayed with an agricultural spreader/sticker (0.14 ml l^{-1}). The third plant at each site was treated with spreader/sticker and one of the repellents. At five sites, SeaCure was applied (8.0 ml l^{-1}). At another six sites, 3-methyl-2-hexanoic acid was applied (0.42 ml l^{-1}). At the remaining five sites, BGR was applied as an even coating (manufacturer's instructions). At each site, plants were approximately 10 m apart. After 6 weeks, only plastic netting and BGR appeared to reduce browse damage. SeaCure and 3-methyl-2-hexanoic acid were ineffective. In experiment 2, ten of the original 16 residential sites were selected. SeaCure and 3-methyl-2-hexanoic acid were reapplied at ten times the concentration used in experiment 1, and damage was evaluated 3 weeks later: neither substance reduced damage. In experiment 3, plants at the remaining six sites were sprayed with BGR or spreader/sticker, or were netted. Plants were spaced ~30 m apart, and damage was evaluated after 3 weeks. Neither BGR nor netting conferred significant protection.

Keywords: arborvitae; Big Game Repellent; human scent; *Odocoileus virginianus*; repellent; rhododendron; SeaCure; white-tailed deer; yew

More agricultural and forest damage is attributed to white-tailed deer (*Odocoileus virginianus*) than to any other vertebrate in the eastern United States (Conover and Decker, 1991). In Pennsylvania, for example, once common plants such as the Canada yew (*Taxus canadensis*; Martin, Zim and Nelson, 1951), are now scarce, and overbrowsing by deer is blamed (Atwood, 1941; Alverson, Waller and Solheim, 1988; Allison, 1990). Not surprisingly, ornamental *Taxus* spp. also are heavily damaged (Alverson *et al.*, 1988; Conover and Kania, 1988).

To date, deer-control activities have focused on increasing hunter access to private lands (e.g. Atwill, 1991), manipulating hunting seasons (Conover and Decker, 1991) and erecting deer fences (Caslick and Decker, 1979). These techniques may be effective, but lethal control is not feasible in many suburban and urban areas, and fencing is sometimes too expensive.

Candidate repellents that protect localized areas from severe browse damage are being sought. Among commercially available products, Big Game Repellent (BGR; Intagra Corp., Minneapolis, Minnesota, USA) has been shown to repel white-tailed deer and other herbivores from non-food crops and landscape plantings (Harris, Palmer and George, 1983; Conover, 1984; Scott and Townsend, 1985; Conover and Kania, 1987; Conover and Swihart, 1990). However, BGR may soon become unavailable, as registrations with the US Environmental Protection Agency are being cancelled (US Environmental Protection Agency, 1993).

The effectiveness of BGR appears to depend upon the odour of volatile short-chain fatty acids and sulfur compounds (Bullard *et al.*, 1978). Accordingly, we designed the experiments described here to evaluate the relative effectiveness of BGR and two other candidate repellents, one containing sulfurous volatiles (SeaCure, Living Acres, Inc., New Sharon, Massachusetts, USA) and the other, a volatile short-chain fatty acid (3-methyl-2-hexanoic acid). Farmers in Maine report that SeaCure appears to repel deer from crops (E. Butler, USDA/APHIS/Animal Damage Control, personal communication). The fatty acid 3-methyl-2-hexanoic acid is the principal odorous component in human sebaceous gland secretions and, hence, of human hair (Zeng *et al.*, 1992). Anecdotal reports suggest that human hair may repel deer, although

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studies have failed to reveal repellency (e.g. Conover and Kania, 1987).

Materials and methods

Study sites

Sixteen residential sites in the Chestnut Hill and Fort Washington areas of Southeastern Pennsylvania were selected. These locations were spaced at least 1 km apart, and separated by highways. All locations had extensive ornamental tree and shrub plantings, and all showed evidence of deer (i.e. tracks, droppings) and deer overbrowsing (e.g. distinct browse lines on vegetation). Although the number of deer visiting sites was unknown, population estimates for nearby areas (e.g. Schuylkill Valley Nature Center) are high (1.5 deer ha^{-1}; Richard James, Schuylkill Valley Nature Center, unpublished observations).

Three yews (*Taxus* spp.), rhododendrons (*Rhododendron* spp.) or arborvitae (*Thuja* spp.) were selected at each site. Plants were of similar size and approximately 10 m apart. Because three yews, rhododendrons, or arborvitae were unavailable at six sites, small (0.50 m tall) yews (*Taxus hicksii*) were planted, ~10 m apart.

Experiment 1

On 23 November 1992, the 16 test sites were randomly assigned to three groups (SeaCure, $n = 5$; BGR, $n = 5$; 3-methyl-2-hexanoic acid, $n = 6$). Within each group, one plant was randomly selected and treated with one of the candidate repellents. SeaCure (8 ml l^{-1}) and 3-methyl-2-hexanoic acid (0.42 ml l^{-1}) were prepared in an aqueous solution that also contained Science spreader/sticker (0.14 ml l^{-1}; Southern Mill Creek Products Co., Tampa, Florida, USA) and applied with Solo Model 456 sprayers (Forestry Supplies, Jackson, Mississippi, USA). The SeaCure concentration was that recommended for application on the label for this product; the concentration of 3-methyl-2-hexanoic acid was that present in human glandular secretions. Treated vegetation was sprayed until all surfaces appeared wet. For application of BGR, a hand-held sprayer was used to apply an aqueous solution of spreader/sticker (0.14 ml l^{-1}), and then a hand-cranked Armitsu Baby Duster (Encat Products, Mt Prospect, Illinois, USA) was used to apply an even coating of repellent. The mean surface area treated was approximately 3.3 m^2 per shrub. No additional attempts were made to enhance the persistence of the repellents, because pilot testing indicated that all three candidate repellents persisted on vegetation for 3–4 weeks (J. R. Mason, unpublished observations). Different hand-held sprayers were used to apply the spreader/sticker, SeaCure and 3-methyl-2-hexanoic acid.

A second randomly selected plant at each site was covered with Deer-X plastic netting (Dalen Products, Inc., Knoxville, Tennessee, USA). Netting was secured to the ground with large wire staples. The third plant at each site was sprayed with Science sticker/spreader alone, as a control.

Following treatment, one branch on every plant was randomly selected, and the numbers of browsed and unbrowsed apical meristems were counted (Conover, 1984).

All sites were revisited after 3 and 6 weeks. At the 3-week visit, repellents and spreader/sticker were reapplied. In addition, at BGR sites only, a shrub of the same species as those under evaluation was selected randomly at a distance ⩾30 m from the test shrubs. Hereafter, these plantings are referred to as 'distant controls'. A branch on each of these plants was selected randomly, and browsed and unbrowsed apical meristems were counted.

Experiment 2

On 5 January 1993, ten of the 16 sites used in experiment 1 were randomly selected and assigned to two groups (SeaCure, $n = 5$; 3-methyl-2-hexanoic acid, $n = 5$). Two new plantings, spaced 10 m apart, were selected at each site. One plant was selected randomly, and sprayed with spreader/sticker and either SeaCure or 3-methyl-2-hexanoic acid at ten times the concentration applied in experiment 1 (16 ml l^{-1} or 0.84 ml l^{-1}, respectively). The second (control) plant was sprayed with sticker/spreader only. Browsed and unbrowsed apical meristems from randomly selected branches were counted 3 weeks after treatment.

Experiment 3

On 25 February 1993, at each of the six sites not used in experiment 2, three balled and burlapped yews were placed on the ground in widely spaced (⩾30 m) locations. Because the ground was frozen, the shrubs could not be planted. One yew at each site was randomly selected, sprayed with spreader/sticker, and then dusted with BGR. A second randomly selected yew was covered with Deer-X netting, and the third (control) yew was sprayed with spreader/sticker. Three weeks after treatment, browsed and unbrowsed apical meristems were counted.

Analysis

Damage was expressed as the percentage of available apical meristems browsed [(total number of meristems browsed/the sum of browsed and unbrowsed meristems) × 100] (Anderson and Strole, 1992). These percentages were evaluated in analyses of variance (ANOVA). Tukey post-hoc tests (Winer, 1962) were used to isolate significant differences among means.

Experiment 1. Two-factor ANOVAs with repeated measures over plants (repellent-treated, netted, control) were used. Because patterns of browsing were similar after 3 and 6 weeks, only the 6-week results are reported here. The independent factor in the analysis was repellent (BGR, SeaCure, 3-methyl-2-hexanoic acid). For BGR sites only, a single-factor ANOVA was used to evaluate browsing of BGR-treated shrubs, netted shrubs, sticker-treated (control) shrubs and distant control shrubs.

Experiment 2. A two-factor ANOVA with repeated measures over plants (repellent-treated, control) was used. The independent factor in the analysis was repellent (SeaCure, 3-methyl-2-hexanoic acid).

Experiment 3. A one-factor repeated measures ANOVA was used to evaluate percentage damage to BGR-treated, netted, and sticker-only (control) yews. In addition, a two-factor ANOVA with repeated measures over plants was used to compare the results of experiment 3 with those of experiment 1 BGR sites. The independent factor in this analysis was trial (experiment 1 vs experiment 3).

Results

Experiment 1

There were significant differences among sites ($F = 4.64$; 2, 13 d.f.; $p < 0.03$) and treatments ($F = 9.33$; 2, 26 d.f.; $p < 0.001$). Post-hoc evaluation of the former effect showed that overall damage was significantly lower at BGR sites than at SeaCure or 3-methyl-2-hexanoic acid sites ($p < 0.05$; *Figure 1A*). Examination of the latter effect indicated that browse damage was least for netted plants ($p < 0.05$, *Figure 1B*).

Although the interaction among sites and treatments was not significant ($p > 0.10$), BGR-treated plantings appeared to suffer less damage (19.7%) than either SeaCure (80.2%) or 3-methyl-2-hexanoic acid (78.4%) treated plantings (*Figure 1C*). Netted and control plants at BGR sites also appeared to be less damaged than netted or control plants at other sites.

When damage to BGR-treated, netted, control, and distant control plantings was examined, there was a significant difference in damage among the treatments ($F = 18.73$; 3, 9 d.f.; $p < 0.0006$; *Figure 2*). Post-hoc tests showed that distant control plants were significantly more damaged than the others. The mean percentage of browsing on distant control plants (71.8%) was comparable to that on control plants at SeaCure and 3-methyl-2-hexanoic acid sites.

Experiment 2

There were no significant differences among treatments. SeaCure and 3-methyl-2-hexanoic acid plantings received as much damage as sticker-only control plants ($p > 0.50$).

Experiment 3

There were no differences in damage among BGR-treated, netted and control yews ($p > 0.25$). When results from experiment 3 were compared with experiment 1 data, the analysis showed that overall damage in experiment 3 was significantly greater than that in experiment 1 ($F = 10.29$; 1, 9 d.f.; $p < 0.0106$; *Figure 3*). Otherwise, there were no significant effects.

Discussion and management implications

Overall, Deer-X netting provided greater protection from damage than did the repellents. However, even netted plants were browsed. Among the repellents, only BGR appeared to reduce damage. This finding is consistent with other studies of BGR repellency (e.g. Palmer, Wingard and George, 1983; Conover, 1984; Conover and Kania, 1987). BGR is aversive to a variety of herbivores, including white-tailed deer, mule deer (*Odocoileus hemionus*), rabbits (*Sylvilagus floridanus*), and mountain beaver (*Aplodontia rufa*) (Boggess, 1982; Campbell, USDA/APHIS/ADC/DWRC, personal communication; Conover and Kania, 1987; Nolte *et al.*, 1993). To our knowledge, it is the only commercially available repellent that has consistently reduced damage to vegetation in controlled experiments.

The possibility that BGR reduced browse damage on

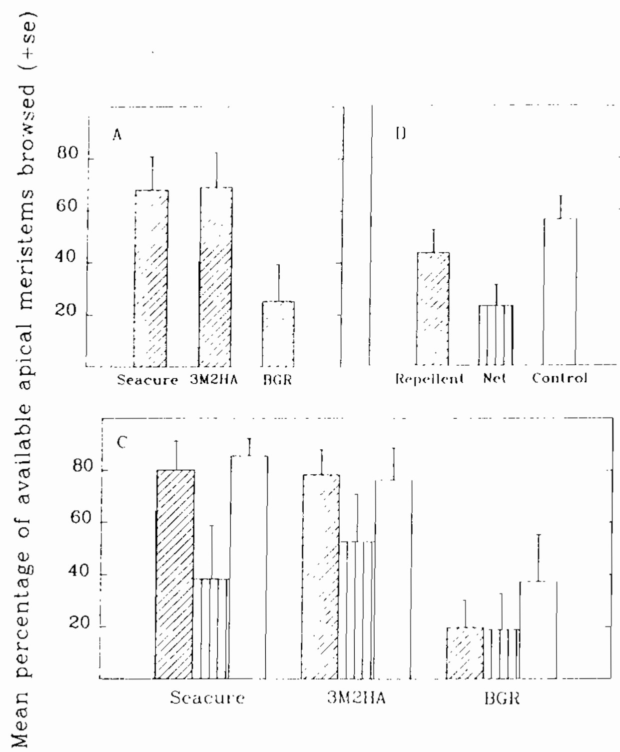

Figure 1. (A) Mean overall percentage of available apical meristems on ornamental plants browsed by white-tailed deer at Big Game Repellent (BGR), SeaCure and 3-methyl-2-hexanoic acid (3M2HA) sites in experiment 1. (B) Mean percentage of apical meristems browsed at repellent-treated, netted (Net) and control sites in experiment 1. (C) Mean percentage of available apical meristems browsed after treatment ( ) with BGR, Seacure, or 3M2HA at 16 sites in experiment 1, compared with netted ( ) or with untreated control (□) sites. Capped vertical bars represent standard errors of the means

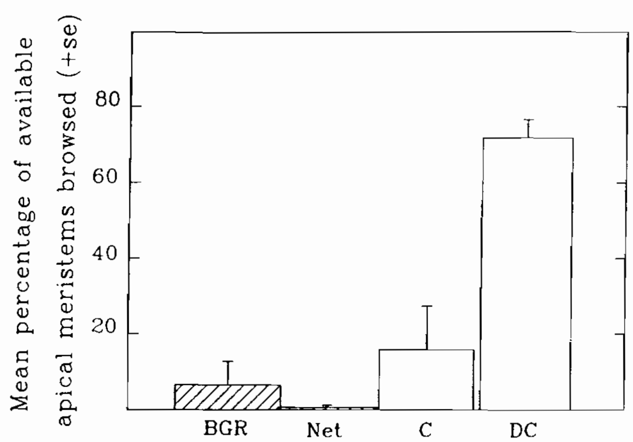

Figure 2. Mean percentage of available apical meristems on ornamental plants browsed by white-tailed deer on Big Game Repellent (BGR) sites only. Capped vertical bars represent standard errors of the means. Net, netted; C, control; DC, distant control

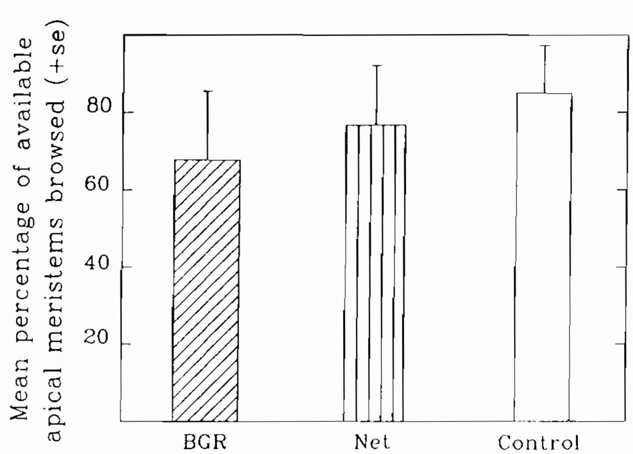

Figure 3. Mean percentage of available apical meristems on ornamental plants browsed by white-tailed deer in experiment 3. Capped vertical bars represent standard errors of the means. BGR, Big Game Repellent; Net, netted

untreated plants in the immediate area of BGR-treated vegetation warrants further investigation. Although the results of experiment 3 failed to support the hypothesis of area repellency, higher overall damage in the final experiment, differences in timing, weather conditions and/or characteristics of treated vegetation (e.g. planted shrubs versus balled shrubs placed on the ground) may have influenced the results.

Contrary to anecdotal claims that human odours are aversive to deer, the results reported here are consistent with other investigations (e.g. Conover, 1984) that failed to reveal any effect of human odour on browsing. This was true both when 3-methyl-2-hexanoic acid was presented at the concentrations in sweat, and when it was presented at ten times that concentration.

In the long term, although repellents and netting may help to alleviate deer damage, neither strategy appears sufficiently effective when deer populations are high (Mason, Bean and Clark, 1993). We speculate that additional control strategies, including population reduction, will be necessary to reduce deer browse damage to socially and/or economically acceptable levels.

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